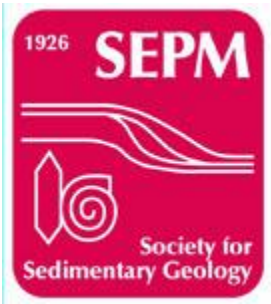

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HOW MANY FOSSIL SPECIES?

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G. G. Simpson (1952) and A. Cailleux (1954) have attempted to guess the total number of species, animal and plant, which may have lived from the beginning of life on earth until the present day. Simpson guessed at something between 50,000,000 and 4,000,000,000 giving 500,000,000 as a possible approximation. Cailleux, taking into consideration his theory of the geometric expansion of life during geologic time (Cailleux 1950, 1952), reduced these estimates to a figure between 17,000,000 and 860,000,000. There seems little ground, however, for his expressed hope that paleontologists may expect ever to know all these species, because these figures include Bacteria, Fungi, Protozoa of various kinds, worms, and a host of other groups which leave few or no preservable traces in the rocks and whose history we shall, therefore, never be able to check fully.

A question of somewhat more practical interest, however, is that of the possible number of *fossil* species, that is, those which we may actually expect to find entombed in the rocks. I have been interested in this question for many years. I have approached it on the basis of several different premises and have always obtained figures that were of the same order of magnitude.

Our starting point must be: How many species exist today whose remains are "fossilizable"? In Table I are listed estimates of the number of known species of all important invertebrate groups whose members have hard covers or skeletons, and which are therefore "fossilizable." These will be of principal use to paleontologists of the future though "unfossilizable" ones that happen to get preserved may sometimes be of greatest interest. The figures for total numbers of living species are a compromise of published estimates by Hesse (1929), Schilder (1949), and Mayr, Linsley & Usinger (1953). The numbers of fossilizable species are little more than guesses, but they should indicate the order of magnitude.

TABLE I

	Total known species	Fossilizable species
Protozoa		
Sarcodina	10,000	10,000
Porifera	4,500	4,000
Coelenterata		
Anthozoa	6,110	5,500
Hydrozoa	2,700	1,000
Bryozoa	3,300	3,000
Mollusca	125,000	120,000
Arthropoda		
Crustacea	25,000	20,000
Echinodermata	4,200	4,200
Total	180,800	169,700

The number of potentially fossilizable noncrustacean arthropods, though very large, is meaningless for our inquiry. There are between 750,000 and 850,000 species of insects alone, but this group has probably risen to its present peak since the expansive development of the angiosperms in the Late Cretaceous. The distribution of insects in rocks is extremely haphazard and it is quite certain that we shall never find the remains of all insect species that ever lived. The same is true for the Arachnoidea and several smaller classes of arthropods.

Schilder (1949), Cailleux (1954), and Mayr, Linsley & Usinger (1953) assume that about one-half of the number of existing species has been scientifically described and named, but it is more than likely that most of the undescribed species will be either insects, or else small, soft-bodied animals and that the percentage of known shell- and skeleton-bearing species is much greater. We may be near the truth, or perhaps err on the optimistic side, if we accept 250,000 as the number of living invertebrate species which are of such a kind and exist under such conditions that their hard parts become easily and normally enclosed in marine or lacustrine sediments. I have no reliable figure for fossilizable annelids, but they may well be included in this generous estimate.

In the Java Sea, according to Martin (1919), no mollusks belonging to still-living species existed in early Miocene time; in Australian waters the first examples of still-

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living species of mollusks appeared in the beginning of the Pliocene, about 12 million years ago (Singleton 1941). The period of time required for a complete renewal of a marine molluscan fauna in a given area would thus appear to be 12 to 20 million years. Schilder (1949) used 15 million years, but since a number of short-lived species appeared and became extinct during such an interval, the lower figure of 12 million years may give more accurate results in extrapolation.

Assuming, then, that this figure is also true for non-molluscan faunas and assuming, further, that the number of contemporaneous species at any one time in the past was about the same as now, we would arrive at a total of 11,250,000 fossilizable invertebrate species (exclusive of insects) for the time since the beginning of the Cambrian. This figure is almost certainly too large, because the number of contemporaneous skeleton- or shell-bearing species in some past periods, for example the Cambrian and the Triassic, was most probably smaller than now.

In 1950, Cailleux suggested that animal life may have expanded geometrically throughout geological time in such a way that the number of animal species doubled approximately every 80 million years. In 1952, Cailleux made a similar calculation for plants. In both cases only a few samples were used (five faunas in 1950, eight floras in 1952) and it seems to me that a great many more statistical studies on the abundance of species in faunas and floras of all ages and from many areas will be required before the law of the "expanding life" can be more accurately formulated. For example, considering the abundance and variety of life in the Late Cretaceous, one might find it difficult to believe that the number of species at that time should have been only half that of the present day. It is even more difficult to conceive of an indefinite continuance of this geometric expansion of life in future eons. Cailleux's formula, according to whether one would take 8 or 12 million years as figures for a complete faunistic cycle, would lead to an estimate of between 3,000,000 and 5,000,000 fossilizable marine species for the entire geologic record, but Schilder (1949) gave an estimate of a possible 5,000,000 for the mollusks alone. Equally unlikely, however, would be to assume that the number of fossilizable species has been constant since the Cambrian. This would give us a total of 11,250,000 species. Obviously, there are more fossil species in the Ordovician than in the Cambrian, but already in the Ordovician the occupation of various biotopes by shell- and skeleton-bearing animals had progressed to a point that from then on the increase in the number of such species has probably slowed down.

The true figure for the total number of fossilizable invertebrate species, and, therefore, of fossil invertebrate species waiting to be collected and described, may be somewhere in the vicinity of 7 or 8 million.

It remains to form a quick estimate of possible figures for vertebrates and plants. Numbers of living vertebrate species are as follows:

Fishes	20,000
Amphibia	2,800
Reptiles	5,500
Birds	8,600
Mammals	13,000
Total	48,900

In what kind of progression various groups of vertebrates have increased (and decreased) would make an interesting study. We may neglect the birds whose complete history we shall never know. Mammals appeared so late that the total number of their species can be assumed to be small, perhaps not more than 100,000, in spite of the shorter survival time of the species. Altogether the total number of extinct vertebrate species, almost all of which would have been fossilizable, is probably not more than one million.

Of vascular plants there are now about 350,000 species (Cailleux, 1953), of others (which are mostly nonfossilizable) 25,000. But the number of vascular plant species must have risen abruptly with the advent of the angiosperms. Estimates of total number of past plant species are, therefore, very difficult to make; also, because of hazards of hazards of preservation, a large percentage was probably never fossilized.

Thus, there are probably good reasons for believing that about 10 million may be the maximum number of fossil species which

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paleontologists of future generations will be called on to describe and that about three-fourths of these will be marine invertebrates, useful and needed in stratigraphic correlation. This number is at least 20, perhaps 50 times as many as the number of fossil species now known to science, but it is slightly less discouraging than Simpson's maximum of 4 billion.

In conclusion, one may feel tempted to quote, somewhat irreverently, from Mark Twain's *Life on the Mississippi:* "There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact." However, there is also a serious message if we look at the task ahead: first, to paleontologists, to put their house in order by organizing their knowledge as well as their taxonomic methods and procedures; second, to organizations which are responsible for the promotion of scientific knowledge, to employ more paleontologists and encourage them to engage in down-to-earth monographic work. This is probably the last time in the history of science that an undertaking such as the *Treatise on Invertebrate Paleontology* can be carried through with the unrewarded labor of love of 120 individual paleontologists. The next time such an organization of knowledge becomes necessary, the wholehearted and official support of geological organizations throughout the world will be required.

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THE USE OF FOOD COLORING AS A NEW TECHNIQUE FOR STAINING MICROFOSSILS

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During recent years the paleontologist has become more cognizant of details of structure and ornamentation of fossil forms and has been confronted with the difficult task of studying, identifying, and describing microfossil shells. This is especially true among the more ornate types of ostracodes in which the maze of minute detail present in the interior or exterior of the valve has made the separation and identification of numerous genera and species very difficult. The ostracode family, Cytheridae, which occurs abundantly in most marine Tertiary beds, and includes numerous diagnostic zone fossils, possesses an unusually high percentage of such ornate representatives. During a comprehensive study of Claiborne ostracodes, it became necessary to develop a new method of bringing forth surficial detail of ornate specimens of this and other families, while not permanently altering or destroying surface features of the type specimens. Green food coloring stain was found to give results superior to that of other types of coloring or staining agents.

Ordinarily, the paleontologist or artist, working with the binocular microscope and occupied with the study of microscopic fossils, sees only specimens which generally lack sufficient contrast to yield adequate de-

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